

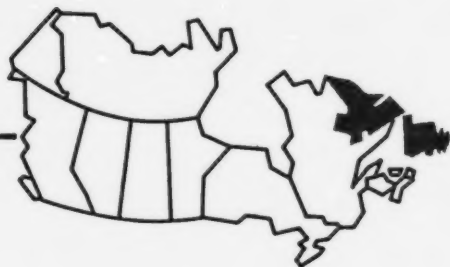


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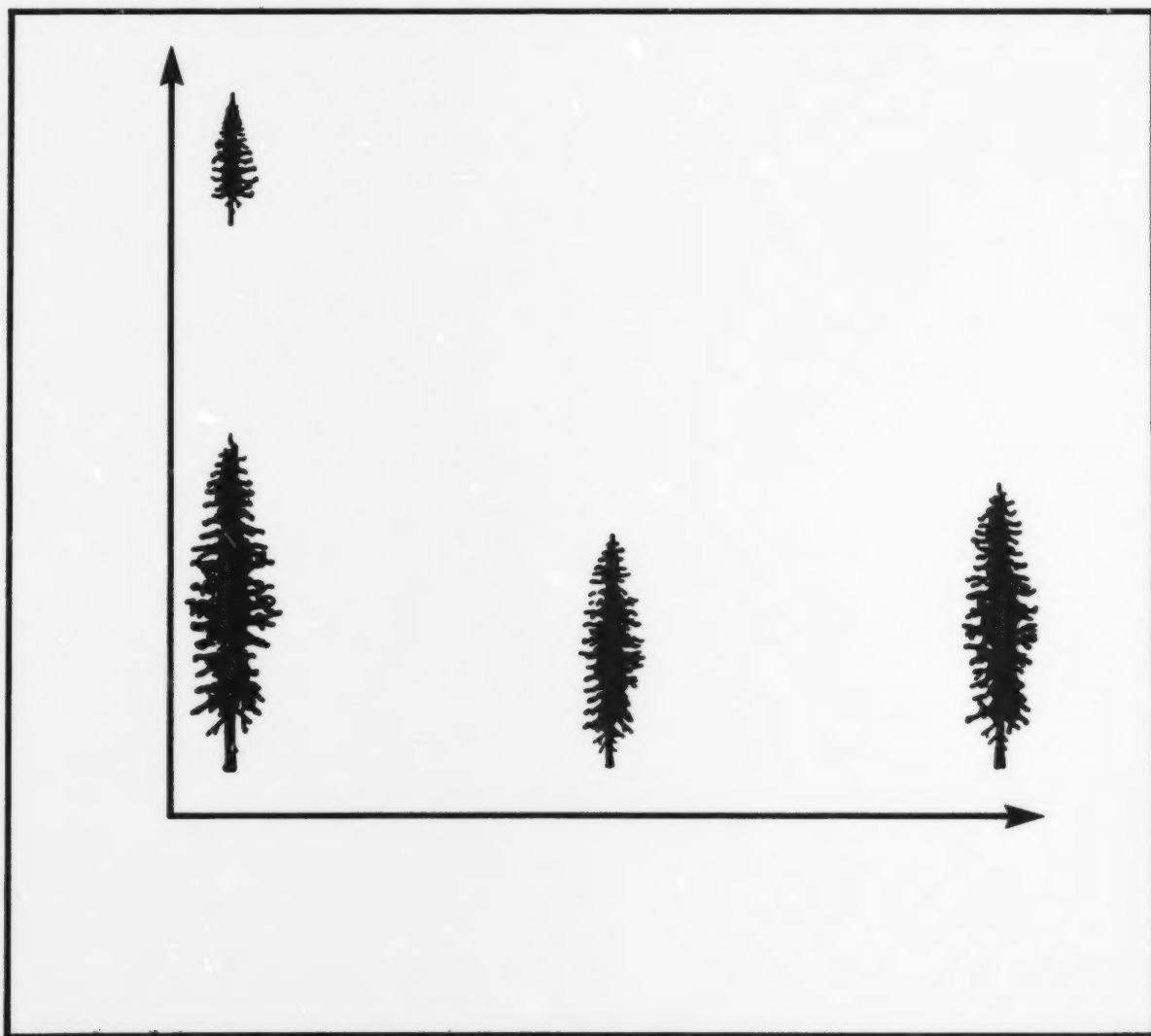
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A Provenance Trial of White Spruce in Newfoundland : Twenty-Five Years from Seed

J. Peter Hall



Information Report N-X-247
Newfoundland Forestry Centre



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by J. Peter Hall

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ABSTRACT

A provenance trial of white spruce in the boreal forest of Newfoundland consisting of seed from the Great Lakes - St. Lawrence Forest Region was measured at 25 years from seed. Provenances from selected locations in the Ottawa Valley and Quebec were consistently superior in growth over time and on different sites and are recommended for reforestation purposes in Newfoundland.

RÉSUMÉ

Les épinettes blanches faisant partie d'un test de provenances mis en oeuvre dans la forêt boréale à Newfoundland et portant sur des semences de la région forestière des Grands Lacs et du Saint-Laurent ont été mesurées à 25 ans (à partir de la graine). On a constaté une croissance supérieure dans le temps et à différents emplacements pour les provenances de certaines parties de la vallée de l'Outaouais et du Québec; ces provenances sont recommandées pour le reboisement à Newfoundland.

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A PROVENANCE TRIAL OF WHITE SPRUCE IN NEWFOUNDLAND:

TWENTY-FIVE YEARS FROM SEED

by

J. Peter Hall

INTRODUCTION

Provenance trials are established to discover the evolutionary trends in species and are used in forest management to select the best available types for reforestation and breeding (Wright 1976). White spruce (Picea glauca (Moench) Voss.) has a wide geographical range in Canada and is an important reforestation species because of its widespread use for both pulp and lumber. Interest in genetic improvement by selection of superior strains has led to the establishment of provenance trials in eastern Canada and the north-central USA (Nienstaedt and Teich 1971, Teich 1973). Results from some of these trials indicated that a 15% increase in height growth could be obtained by using white spruce seed from certain Ottawa Valley sources and these results were consistent throughout the areas tested (Nienstaedt and Teich 1971). This demonstrated increase in yield is a result of selection based on interprovenance variation and is the first stage in genetic improvement of the species.

Forest management programs in Newfoundland envisage the use of several million seedlings annually. Black spruce (Picea mariana (Mill.) B.S.P.) now comprises nearly all plantings but improved forest productivity will rely, in part, on greater use of white spruce because it is

a faster growing species. White spruce is also an inherently more variable species and thus offers greater potential for genetic improvement than black spruce.

As part of research on the growth improvement of native conifers, a provenance trial was established in central Newfoundland in May 1963. Periodic remeasurements have been made at five year intervals from 10 years from seed to 25 years from seed. Results to age 20 have indicated that the best sources are from a group of widely scattered provenances originating from the upper St. John River Valley in New Brunswick to western Quebec (Nicholson 1970, Khalil 1974, 1979, 1985). The 'superior' provenances have remained stable in their ranking over time. Interpretation of the results has been partially confounded by physiographic site differences within the plantation which were described in the first remeasurement (Nicholson 1970). The 25 year remeasurement is considered to be final and the trees are now about halfway through a rotation. The plantation now is maintained as a seed production area and a source for breeding material.

METHODS

Thirty-two provenances were tested, 31 from outside Newfoundland and one from western Newfoundland. The 31 provenances range from northern New Brunswick to northwestern Ontario and south to Michigan (Figure 1, Table 1).

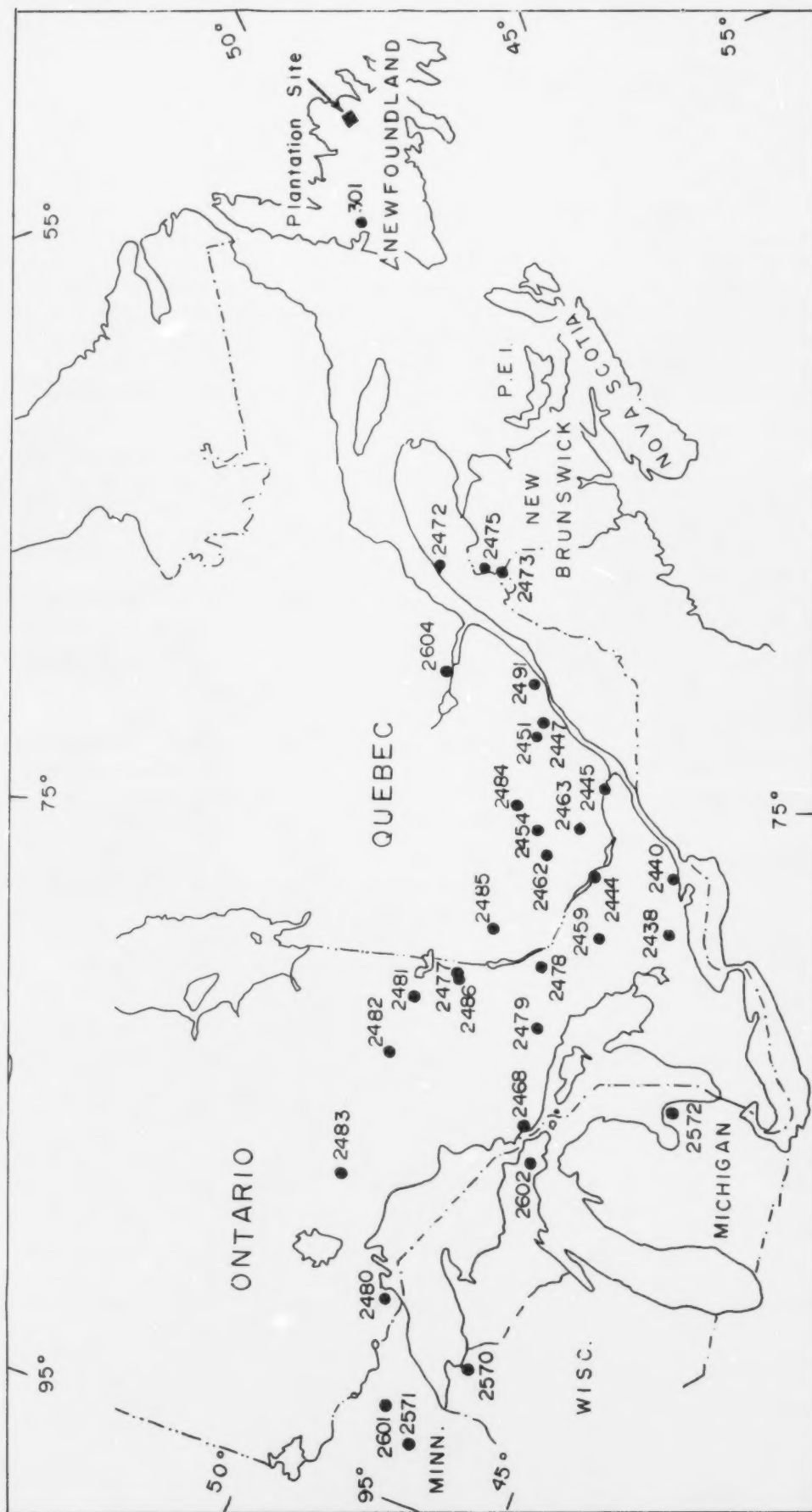


FIGURE 1 - ORIGIN OF PROVENANCES

Table 1. Origin of provenances tested.

Provenance	Latitude (°N)	Longitude (°W)	Eleva- tion (m)	Jan. mean temp. (°C)	Number of frost- free days	Mean length of growing season (days)	Mean annual prec. (mm)
301 Humber Valley, Newfoundland	49.0	57.8	30	-5.1	101	164	1 134
2438 Peterborough, Ontario	44.1	78.0	259	-6.7	150	215	813
2440 Napanee, Ontario	44.1	77.0	91	-6.7	150	215	864
2444 Beachburg, Ontario	45.7	76.8	125	-12.2	130	191	762
2445 Cushing, Quebec	45.6	74.5	76	-10.6	135	189	914
2447 Grandes Piles, Quebec	46.7	73.4	366	-13.9	115	184	889
2451 Lake Edward, Quebec	46.7	72.9	244	-13.9	129	179	889
2454 N. Baskatong Lake, Quebec	47.0	75.6	244	-14.4	100	177	864
2459 Algonquin Park, Ontario	45.6	78.6	427	-11.1	100	178	787
2462 McNally Lake, Quebec	46.5	76.5	244	-13.3	100	184	813
2463 Notre Dame du Laus, Quebec	46.0	75.4	320	-12.2	115	186	914
2468 Searchmont, Ontario	46.8	84.1	335	-10.0	105	181	813
2472 Price, Quebec	48.2	67.8	305	-15.0	90	151	965

..../Cont'd.

Table 1. (Cont'd.)

Provenance	Latitude (°N)	Longitude (°W)	Eleva- tion (m)	Jan. mean temp. (°C)	Number of frost- free days	Mean length of growing season (days)	Mean annual prec. (mm)
2473 Edmunston, New Brunswick	47.4	68.2	198	-13.2	110	173	965
2475 Upper Green River, New Brunswick	47.8	68.3	305	-15.0	90	173	965
2477 Ashley Mines, Ontario	48.0	81.0	341	-16.7	80	167	737
2478 Marten River, Ontario	46.7	79.8	294	-13.3	100	175	838
2479 Aubrey Falls, Ontario	46.8	83.2	381	-12.2	95	160	813
2480 Kakabeka Falls, Ontario	48.5	89.5	274	-15.0	90	163	711
2481 Potter, Ontario	49.4	80.7	290	-18.3	80	153	737
2482 Kapuskasing, Ontario	49.3	83.5	229	-18.9	80	153	711
2483 Pagwachuan Lake, Ontario	49.7	86.1	305	-18.9	80	154	711
2484 Mitchinzeckus Lake, Quebec	47.4	75.1	396	-15.0	90	170	864
2485 Lac Simard, Quebec	47.5	78.6	274	-15.0	95	164	813
2486 Swastika, Ontario	48.1	80.1	305	-16.1	80	167	787

..../Cont'd.

Table 1. (Concl'd.)

Provenance	Latitude (°N)	Longitude (°W)	Eleva- tion (m)	Jan. mean temp. (°C)	Number of frost- free days	Mean length of growing season (days)	Mean annual prec. (mm)
2491 Valcartier, Quebec	46.9	71.5	305	-13.3	110	180	1 168
2570 Chequamegon National Forest, Wisconsin	46.8	91.0	198	-10.6	130	183	711
2571 Grand Rapids, Minnesota	47.5	94.0	411	-15.0	120	182	607
2572 Huron National Forest, Michigan	44.5	83.7	213	-7.2	95	191	711
2601 Cook County, Minnesota	47.7	90.1	198	-10.0	125	165	762
2602 Luce County, Minnesota	46.7	85.3	213	-8.9	140	187	762
2604 Shipshaw River, Quebec	48.7	71.1	296	-16.1	100	160	1 016
Plantation ¹	48.9	54.6	140	-6.2	103	163	1 078

¹Data are from Gander International Airport approximately 35 km north of the plantation.

The plantation is located in central Newfoundland in the Boreal Forest Region B.28(a) (Rowe 1972) at Latitude 48°42'N, Longitude 54°37'W and elevation 140 m. The design of the plantation is a randomized complete block consisting of six replicates and 32 provenances (Figure 2). Plots consist of two rows of 20 trees each planted at a spacing of 1.8 m. Total plantation area is 2.75 hectares.

Seed was sown in the Acadian Forest Experiment Station Nursery in central New Brunswick and the 2 + 2 seedlings shipped to Newfoundland in early May 1963 and outplanted shortly thereafter. The seedlings of the local provenance consisted of wildlings, approximately five years old, which were lifted and planted in October 1963. Thus in terms of growing conditions and planting time the comparison of the local provenance with the others is not entirely valid. Two rows of trees from Provenance 2475 were planted on the perimeter of the plantation (Wilton - 1964).

The experiment is located on the northerly slope of a shallow valley. The site is underlain by glacial till with loamy to clay loam soils. The site formerly supported a mixed stand of black spruce and balsam fir (Abies balsamea (L.) Mill.) with scattered white birch (Betula papyrifera Marsh.) and white pine (Pinus strobus L.). The area was clearcut seven years and burned two years before planting.

Physiographic site conditions are variable within the plantation and range from wet to rapidly drained. Much of blocks 3 and 4 are

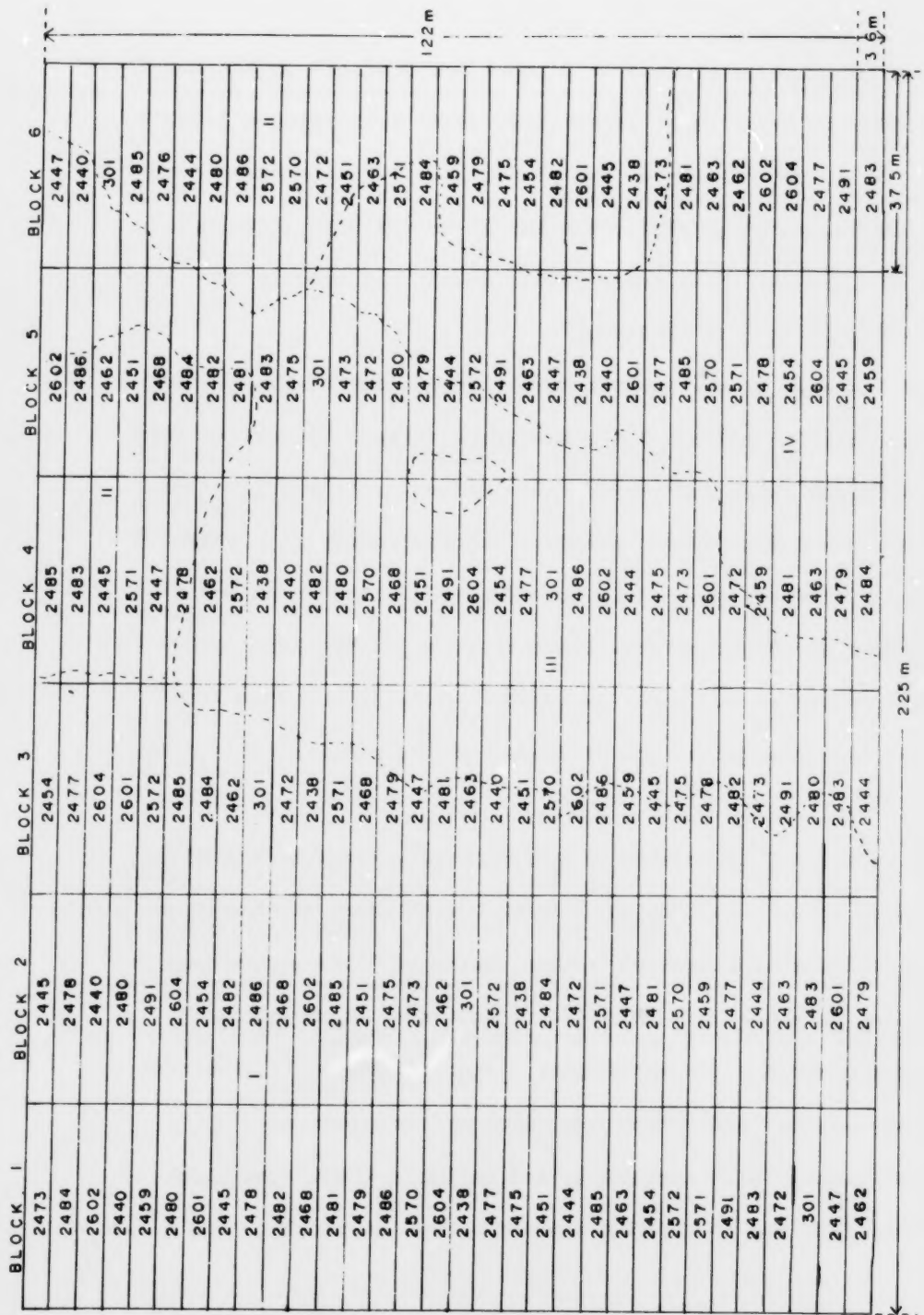


Figure 2. Plantation layout and site types

Site Type

- I. Deep soil and organic layer, fresh well-drained soil
- II. Varying soil depths and moisture conditions, generally moist
- III. Wet site with muck soils, vegetation consists of alder, sedge and sphagnum
- IV. Dry to fresh site, very rocky with moist organic matter burned off

2473-provenance number

poorly drained and growth is poor (Figure 1). Analysis of height data of provenances represented in two different site types showed the differences to be statistically significant¹.

In 1983, at 25 years from seed, all trees in the plantation plus the surround trees were measured for height, diameter and the presence of cones. Data were analyzed by analysis of variance techniques (Steel and Torrie 1960). A preliminary analysis of the surround trees from the lower and upper borders showed growth in the lower border to be significantly better than in the upper border. A correlation analysis of the data (ignoring provenance) with distance, showed a statistically significant correlation between height and distance in four of the six blocks. Means were therefore adjusted by covariance analysis.

Height and diameter were correlated with earlier measurements and with the origin of the provenances. Means were tested using both Duncan's New Multiple Range Test and the Student-Newman-Keul's Test; both of which are recommended for tests of large numbers of means (Douglas et al. 1981).

RESULTS AND DISCUSSION

Survival

Percentage survival 21 years after planting, 25 years from seed, averaged 80.3% slightly less than the 85.7% reported six years after planting (Nicholson 1970). Most mortality in the plantation

¹Unless otherwise indicated a "significant" difference is at $P < 0.05$.

occurred during the first five years after planting but in the following 15 years only 5% of trees died. Most mortality was in the local provenance which had been planted as wildlings. The reduced survival can be attributed to damage to the root systems during excavation and the time of planting. Fall planting of white spruce has resulted in lower survival compared to planting in May (Hall 1977).

Percentage survival reflects site conditions rather than the suitability of provenances. Survival differences among blocks were statistically significant and block variation is a greater proportion of total variation than provenance differences (Appendix I). The wetter areas, Blocks 3 and 4, had about 20% lower survival compared to the fresh to well-drained sites on Blocks 1 and 2. A further indication of the effect of site was a low correlation between survival and height growth ($r = .237$ n.s.). The wet areas which contained dead trees were distributed independently of the provenance location. The relationship between survival and height growth was closer for earlier measurements (Table 2). As the trees age the growth rate appears to reflect more the provenance origin rather than survival.

As stated, survival was statistically significant for blocks and provenances. The ANOVA was unchanged when transformed data were used²; the error term accounted for 45.4% and 43.9% of the total variance using raw and transformed data. Range tests of the means showed the

²Transformation was done using $\sqrt{\arcsin}$ (Steel and Torrie 1960).

Table 2. Correlation (r) between survival, height and factors of the provenance origins.

Average Total Height at Age				Origin of Provenance					
25	20	15	10	Lat.°	Long.°	Elev. (m)	Precipitation ¹	Growing season ²	Temp ³
.237	.299	.485**	.684**	-.242	.387*	.521**	.185	.365**	-.650**

*Significant at P = 0.95, **significant at P = 0.99.

¹Mean annual precipitation (mm).

²Number of frost-free days.

³Mean January temperature.

local provenance to have significantly poorer survival than all others; there were few differences among the others, regardless of the test used (Appendix I).

The correlation of survival with the origin of the provenances had a slight negative correlation indicating slightly better survival for more southerly and westerly provenances (Table 2). Survival increased with elevation and length of growing season and was inversely related to minimum January temperature of the seed sources. The plantation site was at a lower elevation and had generally higher minimum winter temperatures than the areas of origin of the provenances. The interpretive value of these correlations with respect to survival, is confounded by site moisture conditions.

Both longer growing season and milder winter temperatures have beneficial effects on survival. This is reflected by the positive correlations. Most provenances had survival rates in excess of 80%, and on

this basis they are probably useful for reforestation purposes in Newfoundland.

Height and Diameter at 25 Years

Average total height and diameter based on all trees along with the ANOVA are shown in Appendix II. Provenance differences for both were statistically different but variation among blocks was greater than variation among provenances. Differences among provenances were small as measured by Duncan's New Multiple Range Test and nearly non-existent when measured by the Student-Newman-Keul's Test. The SNK Test is considered to be in the mid-range between liberal tests such as Duncan's NMR Test and conservative ones such as the Bonferroni-t test (Douglas et al. 1981).

There were large differences in height attributable to block differences which reduced the precision of the experiment (Appendix II). Growth is better on the fresh to well-drained site of Blocks 1 and 2 than on the wetter areas of Blocks 3 and 4 (Appendix II, Figure 1). Trees in Block 3 growing in the same plot but in fresh and wet sites were compared. Trees on fresh sites (n = 292) averaged 335.0 cm compared to trees on the wet site (n = 125) with 278.5 cm. The differences between the means were statistically significant.

The Newfoundland provenance (#301) after 25 years ranked 26th in height and was 91.8% of the plantation mean. This relatively poor performance is not necessarily a reflection of inherently poor growth or a suggestion that a local strain of white spruce is unsuitable for reforestation purposes. These wildlings suffered severe planting shock during

the first few years after planting and growth at 10 years from seed was only 57.8% of the plantation mean (Nicholson 1970). Biologically this is expressed as planting check (Sutton 1968). Since then provenance 301 has grown at a faster rate than the rest of the plantation and had largely recovered by the time of the second remeasurement (Khalil 1974).

The Newfoundland provenance had been grown under quite different conditions of soil and site management compared to the seedlings grown in the nursery which were preconditioned in their first few years of development. Preconditioning has been shown to influence growth in subsequent stages (Rowe 1964). This is probably the physiological cause expressed as planting check. It does not occur to the same extent in other provenances but separates the Newfoundland provenance from the others.

Correlation Between Growth and Provenance Origin

Although the provenance differences are of limited statistical significance, the growth rates show some correlation with parameters of the origin of the seed sources (Table 3). Both height and diameter

Table 3. Correlation (r) between growth and provenance origin.

Growth	Origin of Provenances					
	Lat.	Long.	Elevation	Precipitation	Frost-free days	Mean Jan. temp.
Height	-.062	-.392* ¹	.227	.286	-.005	-.189
Diameter	-.121	-.396*	.246	.383*	.056	-.238

¹Significant at P = 0.95.

growth are unrelated to latitude; this is not surprising because of the small range of latitude sampled. Growth and longitude were inversely related with better growth for the more easterly ones. The faster growing provenances were all east of a line running due south from James Bay. Growth generally is not closely related to factors of provenance origin. There is no indication of clinal variation as shown by black spruce except the weak cline along longitude.

The pattern of variation in white spruce suggests that provenances from certain areas in the Ottawa Valley and southern Quebec were superior to all others tested. These results concur with results of other provenance trials of white spruce as well as previous results of this experiment (Nienstaedt and Teich 1971, Teich 1973, Khalil 1985). In the Newfoundland plantation, the eight best provenances are from the Ottawa Valley - Southern Quebec, Gaspé Peninsula and northern New Brunswick. The poorest sources are from northern and western Ontario, southern Ontario and from Shipshaw, Quebec. Four of the eight best are from southern Quebec but not all provenances from this area are superior although they are all near or above the plantation mean. It would appear, therefore, that selections of provenances for use in Newfoundland should be concentrated in this area. The variation is unrelated to factors of the environment but rather confined to certain stands within a fairly large area from about 67° to 78° longitude and along 46° to 48° latitude. The same provenances have performed well elsewhere and have been used to establish

planting stock for seedling seed orchards in the Maritimes (Fowler and Coles 1977). This is the next step to be followed in the improvement of the species and gains of 15-20% in height growth can be achieved. An improvement program in white spruce, given these levels of improvement, has been shown to be economically sound (Carlisle and Teich 1971).

Stability of Height Growth over 25 Years

Constant performance over time is an important attribute of a suitable provenance and is a prerequisite for the early selection of a provenance. The stability is shown by the correlation of growth from one period to another (Table 4) and by ranking the provenances over time (Appendix III). All correlation coefficients were statistically significant at $P = 0.99$ and the high levels indicate that provenances which performed well (or poorly) at an early age did so at later ages. Thus it should be possible at the age of 10 years to predict superior provenances; the accuracy of the prediction improves with time.

Table 4. Correlation (r) of height and diameter over 25 years.

Age	Height at Age			Age	Diameter at Age	
	20	15	10		20	15
25	.940	.797	.669	25	.920	.792
20		.877	.718	20		.878
15			.862			

This premise of provenance superiority holds true for provenances as a whole but not necessarily so at the level of individual trees which is the basis of within-provenance selection. Individual tree growth is not necessarily the same when trees are grown in a stand under competition. The trees in the plantation began crown closure between the ages of 15 and 20 years and tree growth is known to vary with the degree of inter-tree competition - a factor which could affect selection procedures (Switzer and Shelton 1981).

Ranking the provenances at each of the measurements (Appendix III) shows stability over time. Generally the degree of change declined over time and both the best and poorest remained constant in rank. Considering the best eight provenances at age 25, 2447, 2444 consistently were the best; 2472 and 2475 increased in rank over time; 2459 and 2463 fluctuated; and 2571 and 2438 declined. However, at any given age, despite the close correlations, selection of the best eight provenances would have resulted in selection of different ones each time. For instance, selection of 2438 or 2571 at age 10 would have meant selecting a provenance whose performance declined markedly over time. This can be avoided by selecting on the basis of results of two successive measurements. Then provenances whose performance fluctuates widely in the short term can be eliminated and a broad genetic base is maintained even though some 'inferior' sources are inevitably included with the 'superior' ones. Other approaches to early selection based on biochemical or physiological methods will eventually improve the value of the selections.

Effects of Slope on Height Growth

At the time of the ten-year remeasurement it was noted that the trees in the lower part of the plantation were growing faster than trees in the upper part. The long axis of the blocks paralleled the direction of the slope and growth declined with increased elevation (Nicholson 1970). Height differences were tested for surround trees from the upper and lower borders and were found to be significant in Blocks 1 to 4 but not in Blocks 5 or 6. This indicated that growth was still affected by slope. The plot means were then correlated with distance up the slope, ignoring provenance differences. Correlations in Blocks 1 to 4 were statistically significant and were $-.869$, $-.869$, $-.830$ and $-.544$ respectively; correlations were less than $.100$ in Blocks 5 and 6. Thus slope position had a significant effect on growth. Correlation of height of the surround trees - all of one provenance - with distance up the slope resulted in an r value of $-.978$, a further demonstration of the decrease of growth rate with elevation.

(1) Analysis of variance, Blocks 1-4

An analysis of variance was computed for the four blocks showing significant slope effects and compared to the results for all six blocks. The ANOVA was more efficient when based on the four blocks with provenance variance accounting for 37.7% of the total compared to 18.8% when all six blocks were used. The range of means also was increased (Appendix IV) although the plantation mean was unaffected. A larger standard error of the mean and less precision resulted when the number of replications was

reduced from six to four. However, this was more than compensated by the increased range of means and more significant differences resulted.

A comparison of the ranking of the means using both methods showed substantial changes in rank (Appendix V). Correlation of the sets of means based on six and four blocks showed a close correlation ($r = .962$), however the four best provenances (2444, 2447, 2472 and 2475) remained in the top four positions but others from the upper and middle ranks changed position considerably. The poorest eight provenances changed little in rank. Site conditions do not greatly affect the best or poorest provenances which remain stable but middle ranking provenances are less stable and more sensitive to site conditions. White spruce is affected in growth rate by site, to the extent of forming site related ecotypes (Teich and Holst 1974). When site is considered the best eight provenances, based on measurements of all data at age 25 and over time (10-25 years) could be reduced to four. These four originate from widely separated areas (Table 5). Three other provenances also remain in the top eight using these criteria, only 2462 drops out to be replaced by 2479.

Table 5. Origin of 'superior' provenances based on data adjusted by site effects.

Provenance No.	Origin	Lat.	Long.	Elev.
2444	Beachburg, Ontario	45°42'	76°48'	125
2447	Grand Piles, Quebec	46°42'	73°24'	366
2472	Price, Quebec	48°12'	67°48'	305
2475	Upper Green R., New Brunswick	47°48'	68°18'	305

(ii) Covariance analysis of data

In an attempt to remove the artificial variation introduced by the change in site quality with elevation, a covariance analysis was performed on the data. The analysis adjusted the mean height of the provenances based on the assumption that the better site conditions at the lower end of the plantation prevailed throughout. After this adjustment, the overall plantation mean increased from 318.6 cm to 391.0 cm but the range of means was reduced (Appendix VI). This resulted in fewer significant differences as measured by the range tests. The standard errors were essentially unchanged by the covariant analysis, from 24.45 to 23.74 after adjustment. The means give a more realistic estimate of the potential of the various provenances when planted under less limiting site conditions. Sites in this area, as in central Newfoundland generally, vary widely in quality over short distances. The plantation covers 2.75 ha and represents wide variations in site which, because of the large plot size, are not replicated for all provenances.

The means obtained by analysing data in Blocks 1-4 and those adjusted by covariance analysis were well correlated ($r = .825$) with each other and the adjusted means are also closely related to the means from analysis of unadjusted data from all blocks ($r = .867$) (Appendix V). Changes in ranking occur mainly in the middle range with provenances at the ends of the scale changing little. The four superior provenances (Table 5) occupy four of the top five places with #2485 now ranking fourth. (This provenance ranked thirteenth in field measurements based on

all six replicates and seventeenth in data from Blocks 1-4.) The provenances, i.e., 2444, 2447, 2472 and 2475, are recommended for use in reforestation programs. To maintain a broad genetic base, however, more provenances should be included. Provenances suggested for inclusion are 2451, 2459, 2463 and possibly 2462. The choices are similar to those suggested based on other measurements; the choices are confirmed when site differences are considered. Provenance studies in white spruce outside Newfoundland have reported provenances from the same general area to be superior in similar tests (Nienstaedt and Teich 1971, Teich 1973).

Within Provenance Variation

Variation exists among provenances and among trees within seed sources. This variation will be exploited in a tree improvement program. Variation in height was measured by the coefficient of variation (CV) for each plot and the ANOVA of these data showed both plot and block differences to be significant. Levels of CV ranged from 30.1% to 18.4%.

The provenances with the best height growth did not have the highest levels of variation however (Appendix VII). Average height and CV were inversely related suggesting that the faster growing provenances were less variable than the slower growing ones ($r = -.505$). There is no obvious explanation for this. It is possible that the fast growing provenances have fewer slow growing inbred trees than the slow growing provenances. If the greater vigour of some individuals in these provenances resulted in selection against slow growth at earlier stages, i.e., in the nursery, then this could result in reduced variability later. Poorer provenances could have had inbred progeny surviving - this would lower

the provenance mean but maintain a pool of very poorly growing individuals included with some better growing ones.

Flowering

Many of the trees in the plantation have been producing cones and viable seed for several years. Overall 14.1% of trees produced cones in 1983. The percentage of trees producing cones varied widely among provenances from 3.9 to 27.4% (Table 6). There was also wide variation among blocks with the wettest one, Block 4, having the highest proportion of trees flowering.

The relationship between flowering and provenance means was negligible (Table 7). Provenance origin had some effect: increased flowering of lower elevation and higher precipitation origins. This may be accounted for by the fact that the plantation site was also in a low elevation, high precipitation zone. Temperatures of the origin of the provenances had no effect. The weak correlations suggest that other factors, probably genotype, have greater effect on flowering than any of the measured variables.

Table 6. Percentage of trees flowering in each provenance and each block.

Provenance	Rank ¹	% Flowering	Provenance	Rank	% Flowering	Block	% Flowering
2444	1	13.2	2438	17	16.0	1	12.3
2447	2	27.0	2484	18	9.9	2	9.5
2472	3	17.3	2445	19	12.3	3	17.0
2475	4	15.3	2486	20	25.4	4	24.0
2451	5	18.4	2572	21	9.8	5	18.3
2462	6	10.9	2602	22	15.3	6	4.8
2459	7	4.9	2571	23	3.9		
2463	8	12.1	2570	24	10.4		
2481	9	12.3	2478	25	9.1		
2483	10	17.4	301	26	27.4		
2477	11	5.9	2604	27	9.2		
2473	12	23.2	2482	28	18.8		
2485	13	6.7	2601	29	18.2		
2454	14	12.8	2468	30	13.8		
2479	15	12.6	2440	31	13.6		
2491	16	15.7	2480	32	25.9		

¹Rank based on data from all trees.

Table 7. Relationship between percentage of trees flowering to growth and origin of the provenances.

Growth		Origin of the Provenances					
Height	Diameter	Lat.	Long.	Elevation	Precipitation	Frost-free days	Jan. temp.
-.068	-.059	.285	-.305	-.321	.349* ¹	-.030	.008

¹*Significant at P = 0.95.

CONCLUSIONS

A 25-year-old provenance trial of white spruce provenances is used to recommend certain seed sources for use in reforestation programs in Newfoundland. Variability in site moisture and fertility confounded interpretations of the data but statistical analyses were used to compensate for these factors. The average height of the best provenances was stable and consistent over variable sites and over time. The provenances recommended for use in reforestation are based on data adjusted for site. They are 2444, 2447, 2472 and 2475; also worthy of consideration are 2451, 2459, 2463 and 2462. Results are consistent with those reported elsewhere. Direct comparison with the local seed source is not possible because wildings were used instead of nursery grown stock.

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APPENDIX I. Ranking of survival of each provenance and block ANOVA, survival 21 years from planting.

Ranking of Survival		Results of Range Test ¹	
Prov.	Surv. %	Duncans	SNK
2459	93.8		
2438	89.8		
2445	89.1		
2485	88.7		
2481	87.9		
2484	87.9		
2463	86.3		
2571	86.1		
2601	85.3		
2462	85.2		
2477	84.9		
2468	84.6		
2570	84.5		
2479	84.0		
2454	82.7		
2491	82.1		
2447	82.0		
2483	81.9		
2451	80.8		
2473	80.8		
2572	80.8		
2472	77.9		
2604	77.1		
2480	76.5		
2482	75.4		
2475	74.9		
2478	73.5		
2602	73.3		
2444	72.7		
2486	70.8		
2440	70.0		
301	51.7		
Plantation			
Mean		80.3	

Analysis of variance - survival				
Source	dF	SS	MS	F
Prov.	31	11 389	367	2.74***
Blocks	5	13 694	2739	20.44***
Error	155	20 819	134	
Total	191	45 902		

***Significant at P > .001

Block No.	% Survival
1	89.8
2	92.3
3	77.0
4	70.8
5	70.4
6	76.9

¹Steel and Torrie 1960, P = 0.95.

APPENDIX II. Rank of mean height and diameter at age 25; ANOVA of height and diameter at age 25.

Ranking of Means		Results of Range Test ¹		Prov.	Diam. (mm)	Results of Range Test	
Prov.	Height (cm)	Duncans	NMR			Duncans	NMR
2444	367.3			2447	57.4		
2447	355.9			2444	54.1		
2472	351.1			2472	52.3		
2475	348.5			2475	51.9		
2451	343.4			2451	51.8		
2462	339.4			2462	51.1		
2459	337.0			2463	50.8		
2463	332.2			2459	50.7		
2481	325.1			2491	48.1		
2483	324.5			2481	47.9		
2477	320.6			2483	47.3		
2473	319.8			2445	46.5		
2485	319.1			2454	46.4		
2454	318.1			2473	46.2		
2479	314.6			2485	46.1		
2491	311.7			2438	45.6		
2438	310.7			2479	45.0		
2484	305.2			2477	44.8		
2445	304.4			2572	44.0		
2486	303.7			2484	43.5		
2572	301.4			2486	43.0		
2602	296.8			2570	41.7		
2571	292.8			2478	41.0		
2570	292.4			2482	41.0		
2478	289.5			2571	41.0		
301	285.4			2602	40.7		
2604	284.5			2604	40.5		
2482	283.8			301	38.1		
2601	277.0			2601	37.4		
2468	267.6			2468	37.2		
2440	257.0			2440	34.2		
2480	251.9			2480	32.4		
Plantation mean	311.0			Plantation mean	44.6		

¹Steel and Torrie 1960, P = 0.95.

APPENDIX II (Concl'd.)

ANOVA	df	Height			Dbh		
		SS	MS	F	SS	MS	F
Provenances	31	125 840	4 059	1.60*	5 779	186	1.65*
Blocks	5	148 915	29 783	11.74***	7 472	1 494	13.22***
Error	155	393 445	2 538		17 476	113	
Total	191	669 200			30 727		

*Significant at $P = .95$, ***Significant at $P = 0.995$.

Height (cm)		Diameter (mm)	
Block	Mean height	Block	Mean diameter
1	360.4	1	56.4
2	330.0	2	49.4
3	292.3	3	41.2
4	279.6	4	39.1
5	297.0	5	42.2
6	291.0	6	39.2

APPENDIX III. Ranking of provenance heights at 25, 20, 15 and 10 years from seed.

Provenance	A G E			
	25	20	15	10
2444	1	2	4	3
2447	2	1	1	1
2472	3	5	12	17
2475	4	4	9	12
2451	5	6	2	6
2462	6	3	8	13
2459	7	8	3	2
2463	8	9	6	8
2481	9	7	5	11
2483	10	14	21	18
2477	11	10	10	16
2473	12	11	15	22
2485	13	15	7	10
2454	14	21	17	14
2479	15	20	23	15
2491	16	12	14	20
2438	17	13	11	9
2484	18	25	29	21
2445	19	16	19	4
2486	20	17	18	24
2572	21	18	26	16
2602	22	23	20	27
2571	23	22	13	7
2570	24	19	16	23
2478	25	24	22	29
301	26	31	32	32
2604	27	28	30	28
2482	28	29	24	25
2601	29	26	31	31
2468	30	27	25	19
2440	31	32	28	26
2480	32	30	27	30

APPENDIX IV. Comparison of mean height from Blocks 1-6 and Blocks 1-4.

Blocks 1-6				Blocks 1-4			
Prov.	Mean (cm)	Range Test		Prov.	Mean (cm)	Range Test	
		Duncans	NMR SNK			Duncans	NMR SNK
2444	367.3			2444	399.5		
2447	355.9			2472	382.7		
2472	351.1			2447	381.3		
2475	348.5			2475	380.2		
2451	343.4			2463	365.2		
2462	339.4			2459	351.4		
2459	337.0			2479	340.8		
2463	332.2			2451	340.0		
2481	325.1			2483	339.4		
2483	324.5			2462	337.6		
2477	320.6			2481	335.9		
2473	319.8			2477	324.9		
2485	319.1			2491	324.4		
2454	318.1			2454	320.4		
2479	314.6			2572	318.2		
2491	311.7			2484	315.6		
2438	310.7			2485	315.4		
2484	305.2			2438	313.6		
2445	304.4			2473	310.7		
2486	303.7			2571	308.9		
2572	301.4			2570	297.6		
2602	296.8			2486	297.5		
2571	292.8			2445	296.4		
2570	292.4			2602	294.1		
2478	289.5			301	290.0		
301	285.4			2478	285.6		
2604	284.5			2604	281.6		
2482	283.8			2482	277.9		
2601	277.0			2601	273.0		
2468	267.6			2468	260.2		
2440	257.0			2480	252.8		
2480	251.9			2440	239.9		
Plantation mean 311.0				Plantation mean 318.6			

APPENDIX V. Comparison of the ranking of mean height based on measurements of Blocks 1-6, Blocks 1-4 and adjusted means of Blocks 1-4.

Provenances	Ranking of Means Based on Height (cm) in:		
	Blocks 1-6	Blocks 1-4	Adj. Blocks 1-4
2444	1	1	5
2447	2	3	1
2472	3	2	3
2475	4	4	2
2451	5	8	7
2462	6	10	10
2459	7	6	9
2463	8	5	11
2481	9	11	16
2483	10	9	21
2477	11	12	15
2473	12	19	17
2485	13	17	4
2454	14	14	6
2479	15	7	20
2491	16	13	19
2438	17	18	14
2484	18	16	13
2445	19	23	8
2486	20	22	25
2572	21	15	12
2602	22	24	24
2571	23	20	22
2570	24	21	27
2478	25	26	18
301	26	25	32
2604	27	27	23
2482	28	28	26
2601	29	29	31
2468	30	30	28
2440	31	31	29
2480	32	32	30

APPENDIX VI. Adjusted mean height of Blocks 1-4 and results of range tests (covariance analysis).

Provenance	Mean (cm)	Results of Range Test	
		Duncans NMR	SNK
2447	445.1		
2475	437.8		
2472	425.5		
2485	422.2		
2444	417.4		
2454	412.4		
2451	410.8		
2445	410.6		
2459	409.5		
2462	407.9		
2463	402.5		
2572	398.6		
2484	397.0		
2438	395.6		
2477	393.5		
2481	393.0		
2473	392.2		
2478	388.2		
2491	386.6		
2479	385.9		
2483	384.9		
2571	384.5		
2604	381.2		
2602	380.7		
2486	374.3		
2482	367.9		
2570	363.7		
2468	354.6		
2440	349.7		
2480	349.2		
2601	345.8		
301	342.6		

APPENDIX VII. Average coefficient of variation (CV) for all provenances, Range Tests and ANOVA for CV.

Provenance	CV	Range Test	
		NMR	SNK
2440	30.1		
2572	26.2		
2601	25.9		
301	25.7		
2604	25.3		
2468	24.1		
2477	23.9		
2478	23.9		
2480	23.8		
2602	23.6		
2463	23.5		
2484	23.4		
2438	23.3		
2472	22.8		
2491	22.6		
2486	22.2		
2447	22.1		
2570	22.0		
2481	21.6		
2482	21.4		
2479	21.3		
2475	21.2		
2451	20.5		
2459	20.4		
2444	20.4		
2571	20.3		
2473	20.1		
2485	20.0		
2445	19.6		
2462	19.3		
2483	18.6		
2454	18.4		

A N O V A				
Source	dF	SS	MS	F
Blocks	5	2745.5	549.1	27.46***
Prov.	31	1187.1	38.3	1.92*
Error	155	3095.6	20.0	
Total	191	7028.0		